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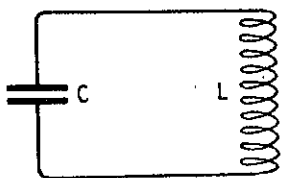
Technical Lesson 25

THE OSCILLATORY CIRCUIT

The oscillatory circuit is one of the most important circuits we will study. It is shown in Figure 1 in its most simple form. It consists of a coil of wire L and a condenser C .

You learned that a coil of wire possesses a property called Inductance, and a condenser the property called Capacity. It was pointed out to you the effect that each of the properties had upon the flow of an alternating current.

In this lesson we shall go further with the study of the effects produced by Inductance and Capacity. You will remember that when we connected a coil of wire, first to a source of direct current, and then to a source of alternating current, both of the same voltage,



the flow of resulting current, measured in amperes, was greater when the coil was connected to the direct current source than to the alternating source. This result was obtained because the counter electromotive force of self-induction in the direct current circuit was only of momentary duration, the effects being noticed only when the current was turned on or off.

The effect produced when the coil was connected to the alternating source, however was quite different. Here the effects of self-induction was found to be continuous, resulting in a back pressure or counter electromotive force, which must always be taken into account whenever the strength of the current is to be determined.

The flow of direct current through the circuit was opposed only by the ohmic resistance, $R = E \div I$, while the flow of alternating current is impeded by the counter electromotive force of self-induction as well as the ordinary ohmic resistance. The additional resistance of self-induction is called REACTANCE and is expressed in equivalent ohms. When these two effects of opposition are present in any circuit it is termed IMPEDANCE, therefore the flow of current through a circuit carrying alternating current will be governed not by the ohmic resistance alone but by the impedance. It must be understood that the counter E.M.F. of self-induction does not represent a loss of energy in an electric circuit as does resistance, where the energy is dissipated in the form of heat, but a greater voltage is required to force a given current through the circuit.

The flow of alternating current is nearly always controlled by coils having the property of high self-inductance and they are called reactance coils. These coils effect an opposition which is termed, Inductive Reactance, and is expressed by the following equation.

INDUCTIVE REACTANCE = $2 \times 3.1416 \times \text{frequency} \times \text{inductance}$

Where 2×3.1416 is a constant

Frequency is the cycles per second

Inductance is the inductance of the coil in henries

This may be written in simple form as follows:

INDUCTIVE REACTANCE = $2\pi \times f \times L$ or $2\pi fL$

2π = 2×3.1416

f = frequency

L = inductance in henries.

When a condenser is connected in series with an alternating current circuit it acts as an effective resistance, as was shown, exerting a back pressure or counter E.M.F. on the electromotive force charging the condenser. This same counter electromotive force exerted by the condenser will also oppose the back pressure set up by the inductance. In order to differentiate between these counter electromotive forces, the reactance caused by the inductance is expressed as positive reactance and that by the condenser as negative reactance. The capacitive reactance of the condenser is shown by the equation;

Capacitive Reactance = $\frac{1}{2 \times 3.1416 \times \text{frequency} \times \text{capacity}}$

or Capacitive Reactance = $\frac{1}{2\pi \times f \times C}$

where $2\pi = 2 \times 3.1416$

f = frequency

C = capacity of the condenser in farads.

When the reactance of the inductance is equal to the reactance of the condenser, their effects are neutralized and the circuit is then said to be in RESONANCE. Resonance in a radio circuit is highly desirable and to obtain resonance the following equation must be satisfied:

$$2\pi fL = \frac{1}{2\pi fC}$$

The frequency is an important factor in any electrical circuit where resonance is desired because if the frequency changes, the value of either the inductance (L) or the capacity (C), or both inductance and capacity values must be changed so that a new point of resonance may be secured.

THE OSCILLATORY DISCHARGE

Figure 2 represents a condenser connected to a direct current charging source. It may, however, be discharged at will by making a metallic connection across the two plates of the condenser as shown in Figure 3.

When making the connection at plate A first, and then bringing the free end of the wire to plate B, a spark will be seen to pass between the free end of the wire and plate B just prior to the actual contact being made. This spark will be only momentary and upon the completion of the spark the condenser will be found to be completely discharged.

In watching the discharge during the short interval of time the spark is visible, it would seem that there had been but one rush of current. In reality, however, there were many back and forward rushes of current while the spark was in evidence. Starting with the positive plate this discharge moves through the connecting wire to the opposite plate making it positive and then discharges back into the first plate. This back and forward rush of current continues, giving up some of its energy at each reversal, which is manifested by light, heat, and sound, until the energy originally stored in the condenser has been dissipated. This back and forward motion of current, or Oscillations of current, then cease.

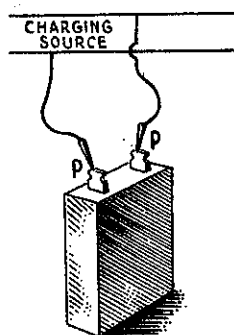


Figure 2

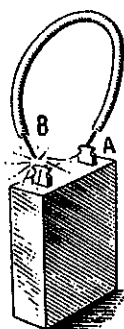


Figure 3

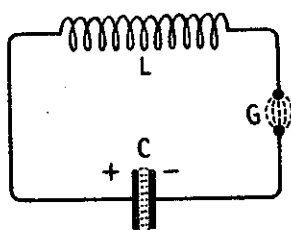


Figure 4

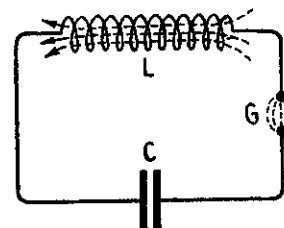


Figure 5

The number of oscillations taking place with a given charge will in this case depend mainly upon the resistance of the path between the two plates. When this path is of low resistance, there will be several cycles of current with each succeeding cycle becoming smaller in amplitude than the preceeding cycle until the current dies out entirely. This gradual dying out of the oscillations is called damping.

A high resistance path will affect the discharge taking place between the two plates because the discharge may take place so slowly that no reversal of current will occur, or because the energy is dissipated in heat.

Let us again charge the condenser and place it in series with an inductance L and spark gap G as in Figure 4. A spark discharge will take place which will consist of a series of cycles of alternating current of constantly decreasing amplitude the frequency of which may be very rapid. These, as stated, are known as damped oscillations. The complete cycle of events taking place in the discharge of the condenser of Figure 4 follow: Just prior to the first discharge which takes place in Figure 4 at gap G , the charge

in the condenser takes the form of an electrostatic field which is stored up between the plates as shown by the dotted lines. This electrostatic field strain is such that it will cause a spark to jump from one electrode to the other across the gap, that is, the collapse of the electrostatic field causes a current to flow across the spark gap through the inductance L which sets up a magnetic field around the coil L and the connecting leads as shown in Figure 5. After the electrostatic field is converted to current the magnetic lines of force will then collapse back upon the inductance L and the connecting leads. The resulting current then recharges the condenser to the opposite polarity as shown in Figure 6. Although the condenser is now charged in the opposite sense the charge is less than that of the initial charge because some of the energy has been lost by the resistance of the current and the production of light, heat and sound.

The condenser now discharges across the gap in a direction opposite to that shown in Figure 5 and the inductance coil L is again sur-

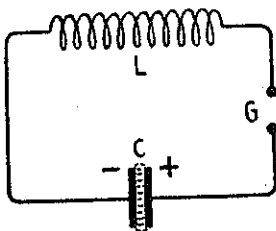


Figure 6

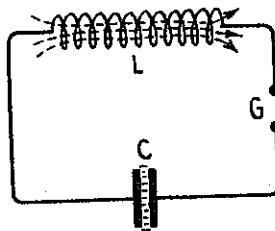


Figure 7

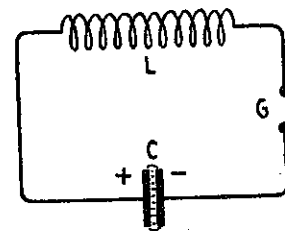


Figure 8

rounded by a field as shown in Figure 7, but opposite in polarity to that of Figure 5.

These magnetic lines of force collapse and the induced current will recharge the condenser again with the polarity as shown in Figure 8.

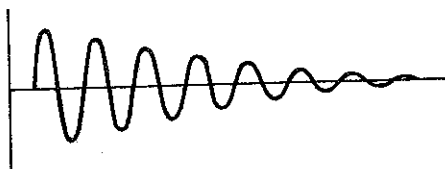


Figure 9

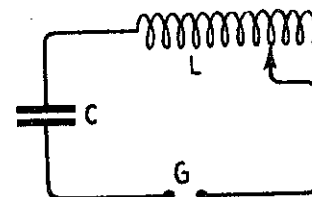


Figure 10

This action continues, with each reversal of current becoming smaller in amplitude than the preceeding one, as shown in Figure 9.

The foregoing may be summed up by saying that when an isolated charge of electricity is applied to a condenser and the plates are connected together by an external circuit the charges do not completely neutralize at the first instant of discharge but, in fact, several alternations of current take place before a state of equilibrium is restored. When we have an inductance coil connected in series with a charged condenser as shown in Figure 10, in which the inductance and capacity can be adjusted to various values, we can, by making the proper adjustments, make the current oscillate many times before it finally ceases.

EFFECT OF RESISTANCE ON OSCILLATIONS

In the circuit just described resistance has a marked effect upon the damping of the oscillating circuit. It is to be noted that, while resistance and capacity will tend to rapidly damp the current in the oscillatory circuit, the inductance present will act the reverse, tending to prolong the oscillations.

Feebly damped oscillations are desired as a general rule, therefore the inductance must be of high value, while the capacity and resistance should be kept at low values.

In laboratory work, when very close measurements are taken of an oscillatory circuit the effective resistance, denoted by symbol R , is always considered. The formula for frequency then becomes;

$$F = \frac{1}{2\pi} \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

Considering the effective resistance " R ", to be zero, equation for frequency would be expressed as follows,

$$F = \frac{1}{2\pi \sqrt{LC}}$$

Resistance, we found, had the tendency to dampen the current in the oscillatory circuit, hence the effects of resistance on oscillations may be expressed as follows: "When in any given circuit a certain critical value of resistance is exceeded, relative to the other factors of the circuit, the circuit will fail to oscillate". The relation, therefore, between the resistance of a circuit and the non-oscillatory condition of the circuit is expressed as follows:

If the resistance denoted by symbol " R ", is greater than $2\sqrt{\frac{L}{C}}$, the circuit will not oscillate.

If the resistance " R ", is equal to $2\sqrt{\frac{L}{C}}$ the circuit is just oscillatory. When, however, the resistance is less than $2\sqrt{\frac{L}{C}}$ the circuit will oscillate because in this case there will be an oscillatory current discharge from the condenser. This circuit therefore is suitable for the production of radio frequency oscillation.

The value of $2\sqrt{\frac{L}{C}}$ is seen to hold a definite relation to that critical resistance which will cause a given circuit to become non-oscillatory. In the above equations

- R = Resistance in ohms.
- L = Inductance in henries.
- C = Capacity in farads.

Let us assume the resistance of Figure 4 to be zero, the frequency, therefore will be expressed by

$$\frac{1}{2 \pi \sqrt{LC}}$$

and it will be found that the frequency of oscillations can be varied over given practical limits by varying either the inductance or capacity values. If, for example, we add turns to the coil L the current will oscillate through the circuit at a lower frequency. When, however, turns are taken off the coil L the frequency of the oscillations increase.

If the capacity of the condenser C is increased the frequency of the oscillations will be reduced and decreasing the capacity will increase the frequency of the oscillations.

RESONANCE

In order to bring out the idea of resonance we will use a circuit as shown in Figure 11, and place close to it another oscillating circuit having variable capacity and inductance but having no physical connection between the circuits. We now have two circuits of radio frequency, LCG, and Ll, Cl, A, coupled magnetically by the inductance coils L and Ll.

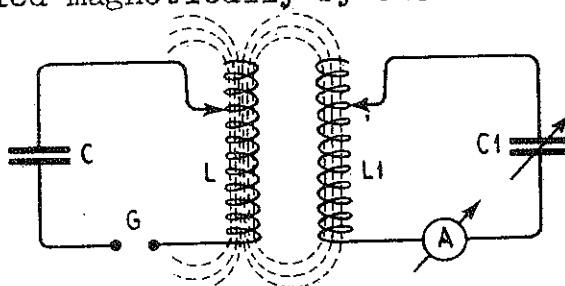


Figure 11

If the circuit, LCG, is set into oscillation and the inductance Ll is carefully adjusted a point will be found when the milliammeter will give a maximum deflection. At any other adjustment of the inductance the meter will indicate a lower reading. It can be shown that the adjustment of the circuit, Ll, Cl, A, when the deflection of the ammeter is maximum, is such that the two circuits have substantially the same period of oscillation, that is, the same natural frequency. It is under such adjustments only that large values of current can be induced in the circuit Ll, Cl, A. The greatest current will flow in an alternating current circuit if it contains inductance and capacity of such values that the reactance of capacity and the reactance of inductance are equal and opposite. This condition exists in the circuit, Ll, Cl, A, of Figure 11 when the hot wire ammeter A indicates the maximum deflection, that is, the reactance of Ll equals the reactance of the condenser Cl, hence the flow of current in circuit Ll Cl is governed by its frictional resistance. The maximum amount of energy will be obtained under these conditions. Figure 12 shows an antenna, inductance coil L and ground. Here we have a circuit similar to the oscillatory circuit shown in Figure 1.

Instead of the small condenser C of Figure 1 we have, in effect, a very large condenser which is formed by the antenna wires and the ground. The aerial takes the place of one plate of the condenser while the ground forms the other plate. The air between the antenna and ground constitutes the dielectric of the condenser. The aerial and ground as stated, forms the plates of a condenser, and connected between is a small coil, L.

The condenser formed by the antenna and ground will be charged by the energy received which is sent out into space in the form of radio waves by a transmitting station. This energy is represented by the curving lines of Figure 12. From the transmitting antenna the energy is radiated through space and as it reaches the large condenser of Figure 12, which is formed by the aerial and ground, a stress is set up which results in a charge on the antenna. This charge causes a current to flow through the coil L to the ground and, in passing through the coil, it sets up a magnetic field about the coil of Figure 12 just as the discharge current from the condenser of Figure 11 set up a magnetic field in the coil L of that circuit.

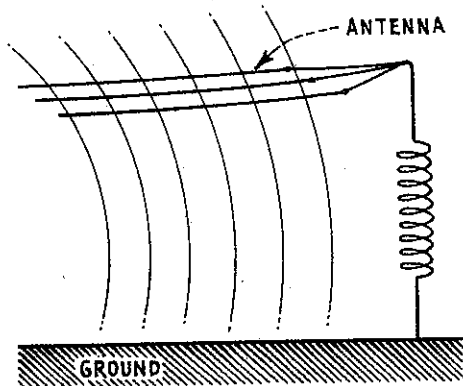


Figure 12

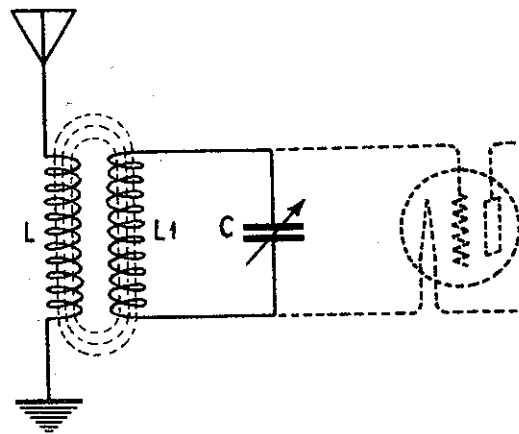


Figure 13

If we inductively couple another circuit containing a coil L_1 and a variable condenser C to the antenna coil L as shown in Figure 13 the magnetic field set up about coil L will cut the coil L_1 and induce therein an E.M.F. which will cause current to flow in the circuit L_1 , C. The value of this induced current will be very small, and we will have to use the principles as set forth under Resonance to utilize this feeble current to the best advantage.

TUNING

The various broadcasting stations transmit energy which energizes the receiving antenna at certain frequencies. Each broadcasting station is allotted a different frequency and it is due to their difference in frequency that we are able to tune broadcasting stations in or out at will.

In tuning, either the inductance or the capacity of the oscillatory circuits of the receiver is adjusted until a point of resonance is

found at the frequency of the station we wish to receive. At this point of resonance the coil L and condenser C of Figure 13 will allow the maximum current flow, offering at the same time a high impedance to any other frequency.

Tuning can be accomplished by using a capacity of fixed value with a variable inductance, or by variable capacity and fixed inductance, or by having both inductance and capacity variable.

Many of the manufacturers, in designing their broadcast receivers, employ fixed inductances and variable condensers for tuning.

Figure 13 shows a variable condenser being used with an inductance and here you have the fundamental circuit of the broadcast receiver.

EXAMINATION - LESSON 25

1. What is meant by resonance?
2. Will a perfect condenser retain its charge over a period of time?
3. When a condenser is discharged is there only one rush of current?
4. Will a high resistance path affect the discharging of a condenser?
5. Explain what you can of the action of the discharging condenser when inductance is in the circuit.
6. Can tuning be accomplished with a variable condenser and fixed inductance?
7. Is it possible to tune a receiving set in which the capacity and inductance are both variable?
8. Which have you found by experience to be the most generally used method of tuning, fixed inductance and variable capacity, or variable inductance and fixed capacity?
9. Does the antenna act as one plate of a condenser? Why?
10. What conditions must be met in an alternating circuit, which contains both inductance and capacity, to obtain a maximum current flow?